USC University of Southern California

USC Viterbi School of Engineering

Department of Astronautical Engineering

ASTE 280 Spring 2025: Foundations of Astronautical Engineering

4 units
Lectures Mondays and Wednesdays 8:00-9:50 AM, VHE 206

Instructor:

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Office Hours: Mondays 10 AM - noon; Wednesdays 12 noon – 3 PM

TA:
TBA

Catalogue Description
Coordinate systems and transformations. Spherical trigonometry. Filtering and estimation. Spacecraft orbits and orbital maneuvers. Rocket propulsion, spacecraft attitude dynamics, spacecraft communications, and space environment.

Course Description
This course is a broad introduction to basic topics in astronautics as well as spacecraft systems. It has the following major topics: Mathematics of coordinate systems and transformations; spacecraft orbits and orbital maneuvers; space environment; rocket engines and rocket vehicles; spacecraft attitude dynamics and control; telecommunications; space power systems; spacecraft structures; thermal protection systems; and spacecraft payloads. This course is required for the B.S. degree in Astronautical Engineering, and is typically taken in the second year.

Learning Objectives

By the end of this course, students will be able to:

- Understand the most common coordinate systems used in astronautics: geocentric vs. heliocentric, inertial vs. body-fixed, and when each one is appropriate.
- Transform between these systems using rotational matrices and quaternions.
- Understand Keplerian orbits and orbital perturbations. Design spacecraft trajectories such as Hohmann transfers, plane changes, and interplanetary trajectories including planetary escape and capture.
- Identify the influences of the space environment on spacecraft design and operations.
- Understand the fundamentals of rocket propulsion, and know the basic characteristics of the different kinds of rockets: solid, liquid, electric. Understand rocket vehicle dynamics: Earth launch, trajectories in the atmosphere, delta-V for orbital maneuvers.
- Understand the basics of rigid body rotations: Euler's equations; orientation angles and quaternions.
- Understand role and fundamental physics behind the various spacecraft subsystems: telecommunications, power, structures, thermal, and payload.

Prerequisites: MATH 226, PHYS 152L

Recommended preparation: Matlab programming

Required Texts

Course notes, to be published on the class website

Description and Assessment of Assignments:

- **Homework**: Written homework assigned weekly and due at midnight on Wednesdays. Homeworks will be graded and returned, generally in one week. Homework solutions will be posted on the class website.
- **Midterms**: Two midterm exams will be given, on Wednesday of Week 6 and Week 12 respectively. The exams will be in the regular classroom, during the regular class time.
- **Final Exam**: The final exam will be two hours, in the regular classroom, Monday May 12, 11 AM-1 PM.

Grading Breakdown

Homework, 15%

1st Midterm Exam, 25%

2nd Midterm Exam, 25%

Final Exam, 35%

Course Schedule

Week	Date	Topics
1	01/13 & 01/15	Class organization. Intro to spacecraft systems, design, operations. Length scales: Solar system and astronomical unit. **Coordinate Systems and Transformations** Types of coordinate systems. Rotations and rotation matrices. Spherical polar coordinates. Orientations: Roll-pitch-yaw and Euler angles. Quaternions. ECI to ECEF transformation. Universal time and Julian date. Solar and sidereal time. **Orbital Mechanics** Gravitational parameter. Solar system data.
2	01/20 & 01/22	Circular orbits. Two-body motion: angular momentum; energy and velocity on orbit. Conic sections. Time since periapsis for elliptical orbits. Classical orbital elements. Flight path angle.
3	01/27 & 01/29	Geostationary and Molniya orbits. Orbital perturbations. Ground track. Hyperbolic orbits. Oberth maneuver. Determining orbital elements from position and velocity. Spacecraft field of view.
4	02/03 & 02/05	Orbital maneuvers. Instantaneous Delta-V. Hohmann transfers. Plane changes. Bielliptic transfers. Fast transfers. Gravity assist. Interplanetary trajectories. Synodic period.
5	02/10 & 02/12	**Space Environment** Components of space environment: Microgravity, radiation, atmospheric drag, debris. Solar output: EM spectrum, solar wind. Cosmic rays. Geomagnetic field. Van Allen belts. South Atlantic anomaly. IGRF model. Effects on electronics: single-event upsets (SEUs) and latch-ups. Radiation-tolerant and radiation-hardened electronics. Shielding to protect electronics. SPENVIS program for calculating radiation exposure in Earth orbit. Spacecraft charging and contamination.
6	02/17 & 02/19	**Rockets and Space Vehicles** Intro to rocket vehicles. Rocket equation. Momentum and pressure thrust. Specific impulse. Liquid-fueled rockets. Thrust coefficient and characteristic velocity. FIRST MIDTERM EXAM.
7	02/24 & 02/26	Optimal nozzle exit area. Solid-fueled rocket motors. Performance of rocket vehicles. Atmospheric drag. Stability of solid rocket combustion. Gravity turn. Staging. Launch sites.
8	03/03 & 03/05	**Spacecraft Propulsion** Need for onboard propulsion: Orbit insertion, stationkeeping, attitude control. Ideal gas law. Spacecraft propulsion system components: Tanks, thrusters, manifolds, valves. Examples. **Attitude Control System** Functions of ACS: Stability, attitude determination, slewing, pointing accuracy. Components: Sensors (star trackers, sun sensors, gyros, magnetometers) and actuators (reaction wheels, gyros, thrusters, torque rods). Moment of inertia tensor. Parallel axis theorem including similarity transform. Addition of mass to align principal axes. Angular velocity and angular momentum. Transformation of time derivatives between rotating and inertial frames. Euler's equations.

9	03/10 & 03/12	Rate of change of Euler angles and quaternion. Full equations of motion for rigid body rotation. External torques on spacecraft. Attitude sensing. Gravity-gradient stabilization. Attitude control: Thrusters and reaction wheels. Angular momentum dumping. Gyroscopic forces. Control-moment and rate gyros. Magnetic torque rods. ACS architectures: Spinning, 3-axis stabilized, momentum bias. Intro to Unix.
		SPRING BREAK
10	03/24 & 03/26	**Telecommunications** Functions of telecom: Command reception, telemetry transmission, and ranging. Components: High-, medium-, and low-gain antennas, transponders, amplifiers. Gain and loss in decibels. Equivalent isotropic radiated power (EIRP). Frequency bands. Loss mechanisms. Noise temperature. Signal to noise ratio (SNR). Link budget. Error correction. Examples. Lessons learned from past missions. **Power Subsystem** Electric circuits: voltage, current, power, resistors, diodes, MOSFETs. Shunts. Photovoltaic solar arrays: I-V characteristics, temperature variation, radiation degradation.
11	03/31 & 04/02	Coverglass properties. Thermal cycling. Radioisotope thermal generators (RTGs). Energy storage: Batteries, fuel cells. Power conditioning systems. Load prioritization.
12	04/07 & 04/09	Solar array and battery sizing. Examples. **Spacecraft Structures** Launch vehicle characteristics: Acceleration and vibration, fairings, payload attachment fittings (PAFs). Materials: Metals, composites, sandwich structures. Deployment mechanisms for solar arrays, booms, and antennas. Structural dynamics. SECOND MIDTERM EXAM.
13	04/14 & 04/16	Resonant frequencies. Lumped-mass approximation. Stiffness analysis using NX. Examples. **Thermal Subsystem** Active vs. passive thermal control. Components: Multilayer insulation (MLI), heaters, louvers, heat pipes, thermal coatings. Thermal sources: Sun, Earth, spacecraft subsystems.
14	04/21 & 04/23	Blackbody radiation. Radiative and conductive heat transfer. Lumped approximation for time-dependent heat transfer equations. Thermal modeling using Thermal Desktop. Examples.
15	04/28 & 04/30	**Payloads** Types of payloads. Payload-specific requirements: thermal, pointing, radiation shielding. Integration with bus subsystems for power, data, and thermal management. Trade-offs: remote sensing vs. in situ payloads. Field-of-view, mass, and power constraints. Imaging telescope design. Examples. Lessons learned from payload failures.

Course Content Distribution and Synchronous Session Recordings Policies

USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. (**Living our Unifying Values: The USC Student Handbook**, page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been distributed to students or in any way had been displayed for use in relation to the class, whether obtained in class, via email, on the internet, or via any other media. Distributing course material without the instructor's permission will be presumed to be an intentional act to facilitate or enable academic dishonestly and is strictly prohibited. (**Living our Unifying Values: The USC Student Handbook**, page 13).

Academic Integrity

The University of Southern California is foremost a learning community committed to fostering successful scholars and researchers dedicated to the pursuit of knowledge and the transmission of ideas. Academic misconduct is in contrast to the university's mission to educate students through a broad array of first-rank academic, professional, and extracurricular programs and includes any act of dishonesty in the submission of academic work (either in draft or final form).

This course will follow the expectations for academic integrity as stated in the **USC Student Handbook**. All students are expected to submit assignments that are original work and prepared specifically for the course/section in this academic term. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s). Students suspected of engaging in academic misconduct will be reported to the Office of Academic Integrity.

Other violations of academic misconduct include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

Academic dishonesty has a far-reaching impact and is considered a serious offense against the university. Violations will result in a grade penalty, such as a failing grade on the assignment or in the course, and disciplinary action from the university itself, such as suspension or even expulsion.

For more information about academic integrity see the **student handbook** or the **Office of Academic Integrity's website**, and university policies on **Research and Scholarship Misconduct**.

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment or what information requires citation and/or attribution.

Statement on University Academic Conduct and Support Systems

Students and Disability Accommodations:
USC welcomes students with disabilities into all of the University's educational programs. **The Office of Student Accessibility Services** (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at **osas.usc.edu**. You may contact OSAS at (213) 740-0776 or via email at **osasfrontdesk@usc.edu**.

Student Financial Aid and Satisfactory Academic Progress:
To be eligible for certain kinds of financial aid, students are required to maintain Satisfactory Academic Progress (SAP) toward their degree objectives. Visit the **Financial Aid Office webpage** for **undergraduate-** and **graduate-level** SAP eligibility requirements and the appeals process.

Support Systems:
Counseling and Mental Health *— (213) 740-9355 — 24/7 on call*
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

988 Suicide and Crisis Lifeline *— 988 for both calls and text messages – 24/7 on call*
The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline consists of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

Relationship and Sexual Violence Prevention Services (RSVP) *— (213) 740-9355(WELL) — 24/7 on call*
Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

Office for Equity, Equal Opportunity, and Title IX (EEO-TIX) *— (213) 740-5086*
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment *— (213) 740-2500*
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

The Office of Student Accessibility Services (OSAS) *— (213) 740-0776*
OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

USC Campus Support and Intervention *— (213) 740-0411*
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity, Equity and Inclusion *— (213) 740-2101*
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency *— UPC: (213) 740-4321, HSC: (323) 442-1000 — 24/7 on call*
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety *— UPC: (213) 740-6000, HSC: (323) 442-1200 — 24/7 on call*
Non-emergency assistance or information.

Office of the Ombuds *— (213) 821-9556 (UPC) / (323-442-0382 (HSC)*
A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

Occupational Therapy Faculty Practice *— (323) 442-2850 or* **otfp@med.usc.edu**
Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.